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INSTRUCTION MANUAL

for the

BA-1 BOLOMETER PREAMPLIFIER

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IM#1
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SECTION 1

GENERAL INTRODUCTION

1.1 Scope of Manual.

This instruction manual covers the description, theory of operation, operating procedure and maintenance of Bolometer Preamplifer BA-1 and BA-1A (Model BA-1 has 0-5ma meter and 1.5 volt battery; Model BA-1A has 0-10ma meter and 3 volt battery.)

1.2 Purpose of Equipment.

The BA-1 Bolometer Preamplifier is a high gain 1,000 cps bolometer preamplifier designed for general use in measuring r-f power level ratios in the frequency range from 20 mc to 40,000 mc or at other frequencies where suitable bolometer mounts are available for use with coaxial or waveguide transmission lines used at the frequency of measurement.

It is particularly suited to the measurement of r-f power level ratios in applications such as antenna pattern measurements, insertion loss measurements and RF amplifier gain measurements, when used in conjunction with other equipment described on page 14 of this manual. Due to the excellent linearity of the amplifier, it is possible to measure directly r-f power ratios of 30 db without switching attenuators, or changing amplifier gain. Low inherent noise levels makes possible such measurements at easily obtained R.F. power levels in the frequency range where bolometers are useful.

1.3 Specifications.

a. Dimensions: Standard relay rack panel 8 3/4" x 19". Maximum depth behind panel 13". Overall dimensions of cabinet 22" x 11" x 15" (29 lbs). Weight including cabinet 49 lbs. Panel, black crackle finish.

b. Ambient temperature: 25°C plus or minus 10°C.

c. Power requirements: nominal 115 V plus or minus 10%, 60 cycles only, 40 VA.

d. Fuse: 3 amps mounted in holder on rear of chassis.

e. Connectors: Input and output are type "BNC" female jacks. Power line input standard 115 volt, 2 wire recessed male cap.

f. Controls: SPST toggle switch controls ac power, ruby pilot light indicates power "on." Two inch knob, marked "Output Control" controls gain of amplifier. Chassis mounted potentiometer controls bolometer bias current.

g. Voltage Gain: Minimum 10,000 when output terminated in external 1 megohm load. Adjustable by means of "Output Control." Gain changes less than .01 db through the range of line voltage of 105-130 volts.

h. Audio Frequency: "Twin Tee" filter for 1000 cps supplied with the instrument; band center frequency 1000 cps plus or minus .5%, 3 db bandwidth is approximately 35 cps. Note: On special order a 400 cps twin tee providing a bandwidth of about 14 cps can be supplied.

i. Maximum Output Voltage: 30 volts RMS into a 1 megohm load.

j. Linearity of Output vs. Input Voltage: Maximum deviation of .1 db up to maximum output voltage of 30 volts. Maximum deviation of .01 db up to maximum output voltage of 3 volts.

k. Linear Range: 60 db, determined at the high end by the non-linearity of .1 db at the 30 volt maximum output, and at the low end by the .1 db error of a linear V.T.V.M. due to the presence of noise. This corresponds to an r-f power level ratio of 30 db at a maximum average r-f power level of 100 microwatts (200 microwatts peak power).

l. Input Impedance: Greater than 2000 ohms. For use with bolometers with DC resistance between 50 ohms and 200 ohms.

m. Output Impedance: Designed for load impedance of 1 megohm minimum.

n. Equivalent Noise: Less than 30 millimicrovolts RMS when connected to a 200 ohm source impedance as referred to the input.

o. Accuracy: .1 db r-f for range of 30 db r-f loss, when using recommended accessories; smaller error for measurement of less than 30 db r-f loss.

p. DC Bias Current: Model BA-1, 0-5 ma ($1\frac{1}{2}$ volt battery); Model BA-1A, 0-10 ma (3 volt battery) adjustable by means of chassis mounted potentiometer. Relay, controlled by power switch, disconnects battery when preamplifier is not connected to line voltage.

q. Protection of Bolometer against Burnout by Transients of Bias Current: Connection or disconnection of bolometer while the preamplifier is "on" will not damage bolometer. Switching power "off" or "on" while bolometer is connected to preamplifier will not damage bolometer.

1.4 Description.

1.4.1 The Model BA-1 Preamplifier is a selective, high gain, low noise, amplifier designed for measurement of r-f power level ratios up to 30 db when used with a typical bolometer and vacuum tube voltmeter.

1.4.2 The amplifier has a self-contained bias supply for the bolometer, together with a meter for monitoring the bolometer current. The circuit is designed to enable the bolometer element to be connected or disconnected without turning off the bias supply and without danger of burning out the bolometer element. The bolometer current meter serves as a convenient r-f overload monitor, further reducing the possibility of accidental bolometer burnout.

1.4.3 The Model BA-1 Preamplifier has a response characteristic sufficiently linear to enable direct measurement of r-f power ratios up to 30 db without switching of attenuators or changing amplifier gain.

1.4.4 The preamplifier has an extremely low noise level which makes it possible to obtain measurements at a low r-f power level, which is usually available and further protects the bolometer element against accidental burnout. This low level of noise has been obtained by careful design of the input circuits; the preamplifier can be operated in the vicinity of a-c power supplies and other 60 cycle equipment without danger of excessive hum pickup by the amplifier.

1.4.5 The input resistance of the preamplifier has been made relatively high compared with the bolometer element resistance to ensure a negligible effect on the voltage applied to the amplifier through variations of bolometer resistance caused by r-f power level changes.

1.4.6 The output resistance of the preamplifier is such as to obtain optimum results when worked into a high impedance vacuum tube voltmeter.

1.4.7 The frequency response of the preamplifier is determined by the plug-in filter network selected. One plug-in unit is furnished for 1000 cps.

1.5 Other Uses For the BA-1 Preamplifier.

1.5.1 Antenna Measurements -- The BA-1 Preamplifier is well adapted to antenna measurements where the detector is either a barretter or crystal diode. For a detailed description of the methods used, see pages 599,602-606 of Volume 12 of Radiation Lab Series, "Microwave Antenna Theory and Design" by S. Silver.

1.5.2 The BA-1 Preamplifier can be used in conjunction with a slotted line to make standing wave measurements. If used with a crystal diode detector, it is necessary to turn the bias control off. It must be remembered that the answers obtained will be power ratios and the crystal diode, if used, should be operated in the square law region of its response characteristic.

1.6 Unpacking and Preparation For Use.

The BA-1 Preamplifier is shipped in a double container with three inches (3") of packing between the inner and outer cases. Normal care should be exercised in removing the instrument from the case, and removing packing material. There should be no loose parts with the exception of the line cord and instruction manual. However, before discarding packing material, search it carefully.

Tubes are shipped in place, as is the 1,000 cps "Twin Tee" filter.

After the instrument has been unpacked, examine it for mechanical damage. If damage is found, notify the shipping company immediately; if none is found, proceed with preparation for use.

1.6.1 Remove the bottom of the chassis and examine the leads going to the floating chassis to insure that vibration in transit has not caused any of these wires to break. Check the fuse to be sure that the 3 amp Bussmann AGC-3 fuse is not broken. Be sure that all tubes are firmly seated in their sockets. Select the audio frequency desired by plugging the appropriate "Twin Tee" filter into the operating socket. Place the unused filter in the storage socket.

1.6.2 The other equipment required will depend on the purpose for which the preamplifier is to be used. (See Section 3). Although the instrument is thoroughly shielded, endeavor to keep it away from high intensity power frequency or r-f fields. To insure greatest accuracy, see that the line voltage is within the operating limits. If necessary, use an A.C. voltage regulator to provide the proper AC line voltage.

1.6.3 The main precaution to be observed when using this equipment is to keep the coaxial cable between the bolometer and the input of the BA-1 as short as conveniently possible. Under no circumstances, allow it to exceed three feet in length. Do not place the BA-1 next to the audio modulator for the R.F. source. Avoid ground loops when connecting your shielded cables. Do not place the BA-1 in the same metal rack with the audio modulator. When laying out the equipment, take care to keep the cable well away from transformer fields and other high intensity magnetic areas. If a stabilized voltage regulator is used, keep it as far away as conveniently possible from the test set-up.

1.6.4 When first switching on this equipment, a sudden full scale deflection of the bolometer bias meter may be observed. This is of no importance and is caused by the bypass condenser charging current. IT DOES NOT INDICATE ANY DANGER TO THE BOLOMETER AND WILL NOT AFFECT IT. A similar deflection to the left is observed when switching off the A.C. line. AGAIN THIS DOES NOT AFFECT THE BOLOMETER.

SECTION 2

THEORY OF OPERATION

2.1 RF Attenuation.

The unknown attenuation of a microwave component may be determined very conveniently and accurately by a method of measurement known as the "Ballantine Voltmeter Method." (For a discussion of this method, see pages 806-808 and 838-841 of Volume 11 of the Radiation Lab. Series, "Technique of Microwave Measurements" by C. G. Montgomery).

2.2 Equipment Required.

The equipment required to make this type of measurement is tabulated in Table 1. A typical insertion loss test set-up is illustrated in the attached block diagram Drawing B-114-30. Such a test set-up is also shown in the attached photograph P-12. The following general characteristics and precautions apply to the various equipment required in conjunction with the Model BA-1 Preamplifier.

2.2.1 RF Source -- The power source should be a modulated r-f generator with at least 20 milliwatts peak output. It must be 100% square wave modulated from an accurate and stable AF source at 1,000 cps. Both the r-f oscillator and the audio oscillator must be stable in frequency and amplitude, and possess stable duty cycles. The Weinschel Modulated R-F Sources MS-1, MS-2 or MS-3 (50-250, 250-920, 900-2000 mc) are suitable. Some means of controlling the output power level is necessary. This control is generally an integral part of the R.F. source. The square wave modulator may or may not be part of the generator, but it is essential for accurate results that the generator be 100% modulated at the audio frequency to which the amplifier is tuned (1000 cps plus or minus 1%).

2.2.2 When making insertion loss measurements, the device under test is inserted usually between a source and load, both of which have the same impedance matching the characteristic impedance of the line. If the generator's impedance does not match the line impedance, but adequate output is available, the simplest method of providing the proper source impedance is to connect a 10 db pad having a low VSWR in series with the output of the generator. This will "mask" the generator's output impedance and the output terminals of the pad will represent a source impedance which is close to the desired line impedance.

If the generator output level is not sufficient to compensate for the added loss of the 10 db pad, tuning stubs can be used to effect the desired match.

2.2.3 Slotted Line -- The slotted line should have a residual VSWR of 1.04 or better, preferably on the order of 1.02. This is necessary in order to adjust the bolometer mount to match the characteristic impedance of the system. It is good practice to use the VSWR indicator which is the companion instrument to the slotted line used. If the indicated VSWR figure is to be correct, care must be exercised to operate the detector of the slotted line in the square law region. Extreme care must be observed in the selection and use of adapters and connectors from the load side of the slotted line to the unknown component, the tuning stubs and the bolometer mount. The component whose attenuation is to be measured is inserted in the system between the slotted line and the combination of stub tuner and bolometer mount.

2.2.4 Bolometer Mount -- Most of the bolometer mounts recommended do not require a stub tuner ahead in the system for a d-c return. However, if lower VSWR readings are desired, it is important to include stub matching ahead of the bolometer mount. This method of measuring attenuation is limited in r-f frequency range only by the bolometer mount. It can be accomplished at any frequency at which it is practical, and feasible, to match the bolometer mount to the transmission system. The practical frequency range can be considered as extending from 20 mc to 40 kmc. Some of the commercially available bolometer mounts are broad band and can be used over frequency ranges of five or ten to one: examples are the PRD 623 (20-1000 mc) and 627A (500-10,000 mc). These mounts normally do not require matching stubs for good results. Other bolometer mounts require the stubs not only for matching, but also for a d-c return; such a mount is, e.g., the PRD 613.

Below 20 mc, it is necessary to increase the coupling and bypass capacities of most commercially available bolometer mounts. At these lower frequencies, tuning stubs become bulky; therefore lumped tuning or resistive masking with a good 10 db or 20 db pad is more practical. Around 100 mc, a practical double stub tuner can be constructed from General Radio stubs type 874-D50 and type 874-LA Adjustable Line, Tees 874-T and Adapters 874-QNP and 874 QNJ. For convenience of operation, the 2 stubs should be 1/8 wavelength apart and each stub must cover a travel 1/2 λ long. All parts should be clamped solid to a support, e.g., a board. In some instances, the length of these stubs must be increased with type 874-L Line Elements.

2.2.5 The cost of bolometer elements is quite high and they are a nuisance to replace; therefore, every effort has been made in the design of the BA-1 Preamplifier to prevent burnout of bolometer elements by DC surge currents. For example, with a BA-1, it is possible to disconnect and reconnect the bolometer without any danger of burning out the element. It is not necessary to shut off the bias current when so doing. The DC meter indicates the bolometer bias current, and permits adjustment to the correct level. It also gives warning if the r-f voltage becomes too high. Changes in the DC resistance of the bolometer are indicated by changes in bias current. There should be no noticeable change of the meter reading with and without R.F. into the bolometer. If such a change is observed, excessive R.F. power is overloading the bolometer.

2.2.6 Barretter Element -- The barretter in the bolometer mount is biased by a d-c current furnished by the Preamplifier. This current is indicated by the meter on the preamplifier marked "Bolometer Current." It is controlled by a potentiometer on the chassis behind the meter. The bias current should always be within the limits specified by the manufacturer. This current is generally 4.5 or 8.75 milliamperes respectively. If it is desired to use a bolometer requiring 3-10 milliamperes the Preamplifier, Model BA-1A, should be used. When biased as described, the barretter will operate in the square law region (for amount of error, see attached Drawing B-114-33) providing the maximum r-f power level applied is also taken into consideration. The maximum r-f power level for square law detection of a PRD 610A barretter is about 200 microwatts peak power. In a true square law detector, the change in resistance is proportional to r-f power; therefore, the audio voltage developed across the barretter is proportional to r-f power. In other words, for any change in r-f power expressed in db, the resulting change of audio voltage expressed in db is twice the r-f change. Theoretical and experimental studies show that under the above conditions the error in attenuation measurements due to deviation from square law does not exceed .02 db R.F. (actually it is close to .01 db R.F.).

2.2.7 Preamplifier -- The requirements that must be met by the preamplifier to measure a 30 db loss are quite stringent. The manner in which the BA-1 Preamplifier meets these requirements is outlined as follows.

2.2.7.1 Range: A 30 db r-f power change produces a resulting change in audio voltage of 60 db. Since the audio voltage at 200 microwatts peak r-f power is only about 2 millivolts RMS of the 1000 cps fundamental across the barretter, an r-f drop in power level of 30 db to .2 microwatts produces only 2 microvolts of audio across the barretter. In order to measure this range of 2 microvolts to 2 millivolts with a conventional VTVM such as, e.g., a Ballantine Model 300, or Instruments Electronics Model 47, a preamplifier with a gain of 10,000 is required. This is the approximate gain of the Model BA-1 Preamplifier. Such a combination makes it possible to use the VTVM in the range of 20 millivolts to 20 volts.

In order to become completely independent of the calibration of the VTVM, it is recommended that a precision audio attenuator be inserted between the BA-1 Preamplifier and the VTVM (see attached photograph P-12). Our Model 2000-62 and Model CF-1 "A.F. Substitution Attenuator for R-F Square Law Detector" consisting of a power cathode follower and a precision 2,000 ohm stepattenuator (operating at 1,000 cps) should be used if overall accuracies better than .1 are required. However, it must be remembered that the audio attenuator is operating with a very low level 1,000 cps signal. Hence it is not recommended that this type of measurement be attempted using an external attenuator unless a combination shielded instrument similar to the Model 2000-62 or CF-1 is used having an input impedance of at least 1 megohm.

2.2.7.2 Linearity: Most of the commercially available VTVMs can be expected to have some error in linearity over the range required. In order not to add to this error, the preamplifier used must have its output in linear relation to its input. The Model BA-1 Preamplifier has linearity of better than .1 db (audio, i.e., .05 db R.F.) over a dynamic range of 60 db starting at a maximum of 30 volts into a 1 megohm load; while starting at a maximum of 3 volts output, the linearity is better than .01 db (audio, i.e., .005 db R.F.).

2.2.7.3 Noise: The minimum audio voltage when measuring 30 db attenuation under the conditions outlined is 2 microvolts. In order to measure this low voltage level accurately, the noise contributed by the preamplifier should not exceed 1%, if the error in the indication of the VTVM due to the presence of noise is of the same order. The noise level of the BA-1 Preamplifier is about 20 millimicrovolts, referred to the input, when operated with a shielded 200 ohm wire-wound resistor across the input jack.

2.2.7.4 Input Impedance: In order to utilize most of the audio voltage developed across the barretter, the preamplifier should have a high input impedance when compared with the normal barretter resistance of 200 ohms. Changes in the barretter resistance caused by changes in r-f level usually result in a change of the voltage division between the barretter and amplifier input, unless both are purposely mismatched in the right direction. For this reason, the input impedance of the BA-1 Preamplifier is designed to exceed 2000 ohms.

2.2.7.5 Audio Frequency: The frequency used for modulation and detection is determined by two factors. In order to be relatively free from noise, the frequency should be low or high compared with 60 cps, 60 cps harmonics and microphonics. In order to use standard transformer designs, a frequency above 60 cps was chosen. However, due to the thermal time constant (for details, see Weinschel Engineering Co. Inc. Engineering Notes No. 3, April 1955, on "Thermal Time Constant Of a Bolometer") of the barretter, its demodulating efficiency and audio output decreases with increasing frequency. The PRD 610A barretter, for example, has a time constant of about 120 microseconds. Its audio output at 400 cps is reduced by 2 db (audio, i.e., 1 db R.F.) and at 1000 cps by 4 db (audio, i.e. 2 db R.F.) when compared with 100 cps. Therefore, as a compromise, we recommend operation at 1000 cps.

2.3 Extending The 30 db Range.

Power ratio measurements exceeding the normal 30 db range of the equipment described can be made in 2 steps by calibrating a good, low VSWR 30 db pad. With this pad, together with the requirements of raising the r-f level from the 200 microwatts peak power (square wave modulated) to 200 milliwatts peak power, it becomes practical to measure a 60 db loss. It must be remembered, however, that whatever error exists in the calibration of the 30 db pad must be added to the system error. We can supply a 30 db, 1 watt pad calibrated to an accuracy of .1 db. Using such pads, the total error of a single channel system for a 60 db measurement as described above is in order of .2 db.

When extending the range of a single step measurement by using more than 200 microwatts peak power, it is generally desirable to take into consideration the error introduced by the barretter's deviation from true square law response. This error may be approximated and corrected for, by the application of corrections based on the equations outlined in the attached drawing B-114-33. A typical computation of the resultant error is shown below for the PRD 610-A:

Exponent of Resistance of Barretter = n = .9
P_1 = D.C. Bias Power = 4 milliwatts (4.5 MA, 200 ohms)
ΔP = Maximum R.F. Power = 200 microwatts peak
$(n-1)\frac{\Delta P}{P_1} = .005$

Consulting the graphs in Drawing B-114-33, we find maximum error $\approx$ .011 db (R.F.)

This error due to the deviation of the barretter from square law results in a lower measured attenuation value. For correction, it ought to be added to the measured value.

Subject to the limitations due to burnout of the barretter (e.g., 8 milliwatts for the PRD 610-A), one can operate at a higher R.F. power level and make a correction for the deviation. A level of 2 milliwatts peak corresponds for a PRD 610-A to about 20 millivolts, 1,000 cps at the input of the BA-1. According to the above mentioned graph, a measurement of 10 db R.F. loss requires a plus .095 db correction. A measurement of an R.F. loss exceeding 20 db requires a correction of plus .11 db. Using this correction, it is simple to measure a 40 db loss, if the preamplifier could handle the input of 20 millivolts. The BA-1, however, is limited to a maximum input of 3 millivolts.

SECTION 3

OPERATING PROCEDURE

3.1 To Measure Up To 30 db Attenuation.

To make measurements up to a 30 db power ratio, recommended equipment (See Table 1) should be set up as shown in Drawing B-114-30 and in photograph P-12.

It is important that the equipment selected be appropriate for the frequency range desired. The Precision Audio Stepattenuator shown is not necessarily required; however, for more accurate results, it is recommended. The procedure to follow in making measurements is outlined below:

3.1.1 Procedure Without Audio Stepattenuator -- The r-f generator is tuned to the desired frequency and 100% modulated with a 1000 cps square wave. Check the BA-1 Preamplifier to make certain that the 1000 cps plug-in filter unit is in the operating socket. The pad or attenuator to be measured should not be in the circuit at this stage of measurement. Adjust the generator to a low output level to avoid the risk of burning out the bolometer element. Next, tune the slotted line probe to the R.F. frequency for maximum indication on the VSWR meter. Adjust the double stub tuner associated with the bolometer for minimum VSWR. This should be close to the residual VSWR of the slotted line. The system is now tuned to 50 ohms.

Set the VTVM to a convenient db level on the VTVM scale not above 20 volts with the gain setting of the BA-1 at maximum. Increase the r-f generator output level until the VTVM reads 20 volts. For the initial measurements, check the voltage across the bolometer terminal. It has been found most helpful in actual operation to leave a BNC-T connector (e.g., UG-274/U) in the bolometer input terminal of the BA-1. This permits monitoring of the A.C. voltage at the input. Set it to 2 millivolts at maximum R.F. level before insertion of the unknown attenuator for best results. It is well to recheck the VSWR again at this power level. It should be the same as before. Insert the attenuator or pad to be measured between the slotted line and the tuning stubs. Do not change any other adjustments. Read the change of VTVM voltage indicated in db. The attenuation of the inserted attenuator or pad is the ratio in db of the two VTVM voltages read, divided by two.

3.1.2 Procedure With Audio Stepattenuator (Model 2000-62 or CF-1). When employing the Audio Stepattenuator, the procedure is essentially the same except that the VTVM is used at only one constant

level. This eliminates any errors caused by inaccuracies of the VTVM. The Audio Attenuator is used to adjust the VTVM to the same reading and measure the level difference when the pad with unknown attenuation is inserted in the r-f system.

With the audio stepattenuator set at zero attenuation, adjust the power level of the r-f generator until the VTVM reads a maximum of 15 volts; this lower voltage level is necessary because of the loss in the cathode follower of the Stepattenuator. If this precaution is not observed, there exists the possibility of bolometer burnout and overloading of the bolometer preamplifier. For the initial measurements, check the voltage across the bolometer terminal. It has been found most helpful in actual operation to leave a BNC-T connector (e.g., UG-274/U) in the bolometer input terminal of the BA-1. This permits monitoring of the A.C. voltage at the input. Set it to 2 millivolts at maximum R.F. level before insertion of the unknown attenuator for best results. Next, adjust the Audio Stepattenuator to a value several db greater than the R.F. attenuation to be measured. Note the VTVM reading. Insert the R.F. attenuator pad to be measured in the R.F. system and, without any other changes, decrease the setting of the Audio Stepattenuator until the VTVM returns to the same reading as before. The difference between the two db settings of the Audio Stepattenuator is the desired unknown insertion loss of the R.F. attenuator or pad.

3.2 To Measure Attenuation Greater Than 30 db.

It is practical to measure attenuation in excess of 30 db in the following manner. First, calibrate a 10, 20 or 30 db attenuator using the procedure outlined in Section 3.1. This attenuator, e.g., a 20 db pad, is then left in the r-f system and the power level of the r-f generator is increased to produce a reading of the VTVM not exceeding 20 volts (or 15 volts if the Audio Stepattenuator is used). This increases the signal generator level. The "range-extending attenuator" is then removed, and the unknown attenuator, e.g., a 50 db pad, is inserted. The new VTVM reading will be approximately 60 db audio, (30 db R.F.) lower relative to the VTVM reading as set with the standard 20 db pad. This 30 db R.F. figure plus the original figure of calibration of the range extending 20 db attenuator will be the attenuation of the unknown 50 db attenuator. It is advisable for such measurements to adjust the source impedance to Zo (50 ohms) by means of tuning stubs.

With the Audio Stepattenuator in the circuit (See Section 3.1.2), this procedure will be altered only in that the db levels measured and used in the calculations will be obtained from the Audio Stepattenuator which is calibrated to read direct in R.F. db, rather than from the VTVM in audio db which must be divided by 2 to obtain R.F. db. Using this system, it is possible to measure up to 60 db of attenuation, providing the R.F. source is capable of supplying 200 milliwatts peak power from source impedance Zo.

SECTION 4

MAINTENANCE

4.1 Introduction.

The Model BA-1 Preamplifier has been designed to require a minimum of maintenance. However, should trouble develop and service become necessary, the usual procedure for maintenance of vacuum tube amplifiers applies.

4.2 General Maintenance.

4.2.1 Tubes: The checks usually made to determine the condition of vacuum tubes will normally suffice. However, special selection of the output tube V2 (5814) may be required if the noise level is high or if the amplifier has a tendency to be microphonic. Generally, three out of five new tubes tested will be good. The test described in 4.3.1 below should be made if tube trouble of this nature is experienced.

4.2.2 Components: Resistance, capacity and voltage values are shown in the attached drawing C-112-7. Voltage measurements were made using a 20,000 ohms per volt meter. The dry cell used for biasing the bolometer may be replaced by removing the bottom plate off the chassis. Be sure to observe polarity when replacing the battery. To remove or replace battery, loosen screws holding "U" clamp, and slide battery, after disconnecting leads. The "Twin Tee" plug-in units are held close to tolerance and adjusted during manufacture. It is not advisable to attempt any repair of this component. Should the "Twin-Tee" unit become defective, it should be returned to us for repair and adjustment.

4.3 Performance Tests.

If the BA-1 Preamplifier is suspected of faulty performance, several simple tests may be made which will establish its agreement with the major original specifications. These tests are shown below.

4.3.1 Noise: To make a simple check of the noise level of the BA-1, connect a shielded 200 ohm resistor (not film or composition type) to the input of the preamplifier (this may consist of a bolometer mount with no r-f applied to the bolometer element). Connect a VTVM capable of reading .1 MV to the preamplifier output. With the gain control of the preamplifier **set to produce a gain of 10,000, the VTVM indication should not exceed .25 MV.**

4.3.2 Gain: A simple check for gain can be made by connecting a sine wave audio generator to the input of the amplifier. Adjust the frequency of the audio generator for maximum output of the preamplifier at 1000 cps. Set the audio generator level at 1 millivolt. The high

impedance VTVM connected to the preamplifier output terminal should read at least 10 volts. In other words, the preamplifier has a voltage gain of at least 10,000.

4.3.3 Audio Filter -- "Twin Tee": Should the resonant frequency of the filter be suspected, perform Test 4.3.2 at 1000 cps. If a gain of 10,000 is obtained for one filter but not for another one, it is probable that the low filter is faulty. It should be returned for repair. On the other hand, if both filters show similar low gains, it is probable that the trouble lies in the preamplifier -- unless both filters show signs of damage. Standard voltage, resistance and capacity, measurements should quickly reveal the cause of trouble in the preamplifier circuits.

TABLE 1

RECOMMENDED EQUIPMENT

Freq. Range kmcs	Type Trans. Line	Type Bolom-eter Mount	Type Bar-retter	Signal Sources	Slotted Line	Output Level Indicator	Audio Step Atten-uator	VSWR Ind.	Stub Tuner
.20 to 1.00	Coax. 50 ohm	PRD623	PRD629A	HP608A HP612A GR1211A GR1215A GR-1208A GR1209A	100-2000 mc Rollin 62 HP805A 400-4000mc	BAL 300 or IE 47	WEC 2000-62 or CF-1	HP415A	From 4 to 4 kmc WEC DS-109L
1.00 to 10.0	Coax. 50 ohm	PRD627A HP475B PRD613	PRD631C HP G28A PRD610A	HP612A HP614A HP616A HP618B HP624B GR 1218A Oscil-lator Tubes	HP809B PRD200 2000 10,000 mc				From 1 to 10 kmc PRD 306 WECDS109
8.2 to 12.4		PRD613	PRD610A	SP2K39 VAR X-13					
12.4	Wave Guide RG-107/U	PRD616	PRD614	SP SRU-54 VAR X-12 SP SRU-55	HP P810B				
18.0 to 26.5	Wave Guide RG-66/U	PRD621	PRD614	RAY QK-306 RAY 2K33 SPSMK40	PRD211				
26.5 to 40.0	Wave Guide RG-96/U	PRD618	PRD617	RAY QK-289 RAY QK-290 SPSRV38 RAYQK291 RAYQK292	PRD212				

Key:

BAL - Ballantine
GR - General Radio
HP - Hewlett Packard
IE - Instrument Electronic
PRD - Pdytechnic R. & D.
RAY - Raytheon
Rollin - Rollin
SP - Sperry
VAR - Varian
WEC - Weinschel Engr.

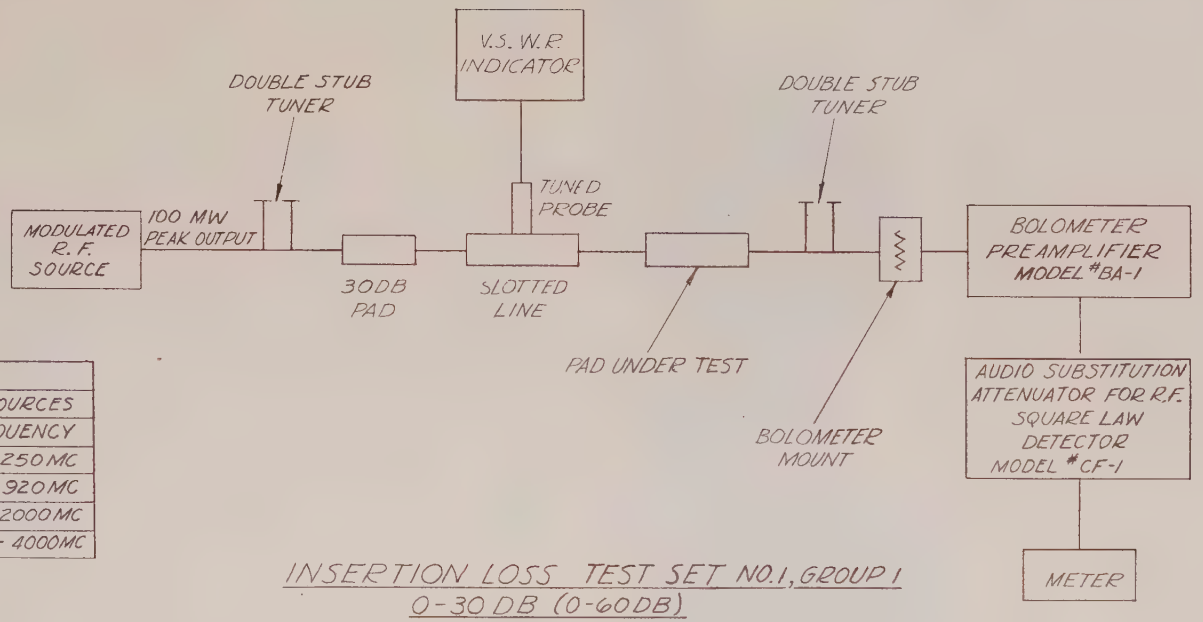
P-3

FRONT VIEW OF MODEL BA-1 BOLOMETER PREAMPLIFIER

B114-30 A

TOLERANCES

ALL 3 PLACE DECIMAL DIMS. ± .003
ALL 2 PLACE DECIMAL DIMS. ± .01
ALL FRACTIONAL DIMS. ± 1/64
ALL ANGLES ± ½°
UNLESS OTHERWISE SPECIFIED



LIST OF MODULATED R.F. SOURCES	
MODEL NO.	FREQUENCY
MS-1	50-250MC
MS-2	250-920MC
MS-3	900-2000MC
MS-4	2000-4000MC

INSERTION LOSS TEST SET NO.1, GROUP 1
0-30 DB (0-60DB)

NOTES:
1- 30 DB CAN BE MEASURED IN ONE STEP BY USING THE BA-1 AND CF-1.
2- IF THE GENERATOR OUTPUT IMPEDANCE IS ADJUSTED TO PRESENT THE PROPER SOURCE IMPEDANCE, THIS RANGE MAY BE EXTENDED TO 60 DB BY THE USE OF A CALIBRATED 30 DB PAD APPLYING THE R.F. SUBSTITUTION METHOD.

REVISIONS

A	REVISED 5-23-55	WHA

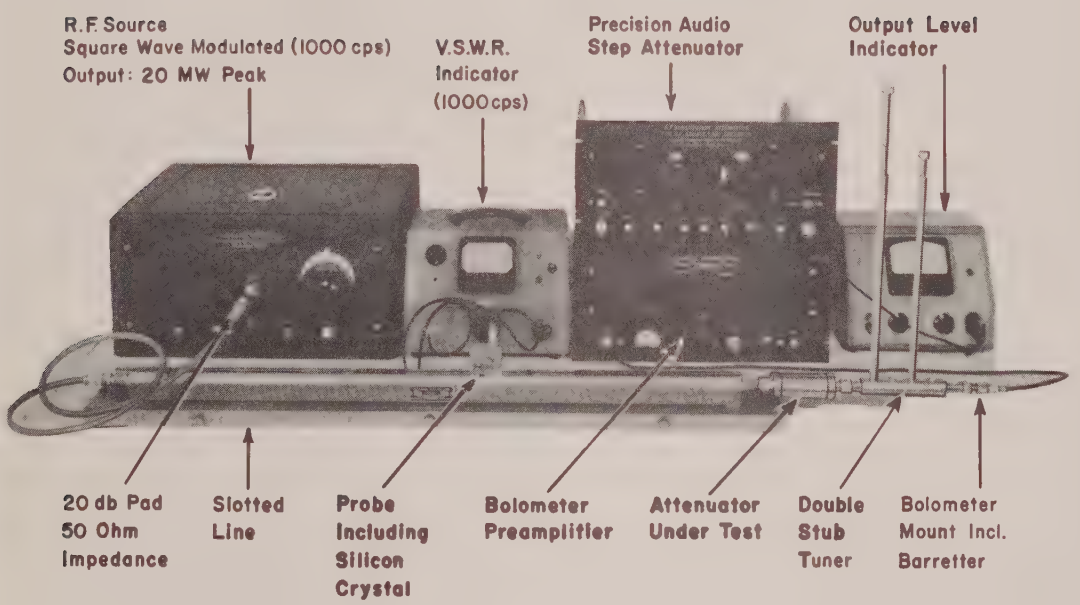
USED ON	ASSY. DRWG.

Weinschel Engineering Co.
SILVER SPRING, MD.

INSERTION LOSS TEST SET NO.1, GROUP 1 0-30DB (0-60DB)

MATERIAL
FINISH
D C
T
SCALE
B 114-30 A

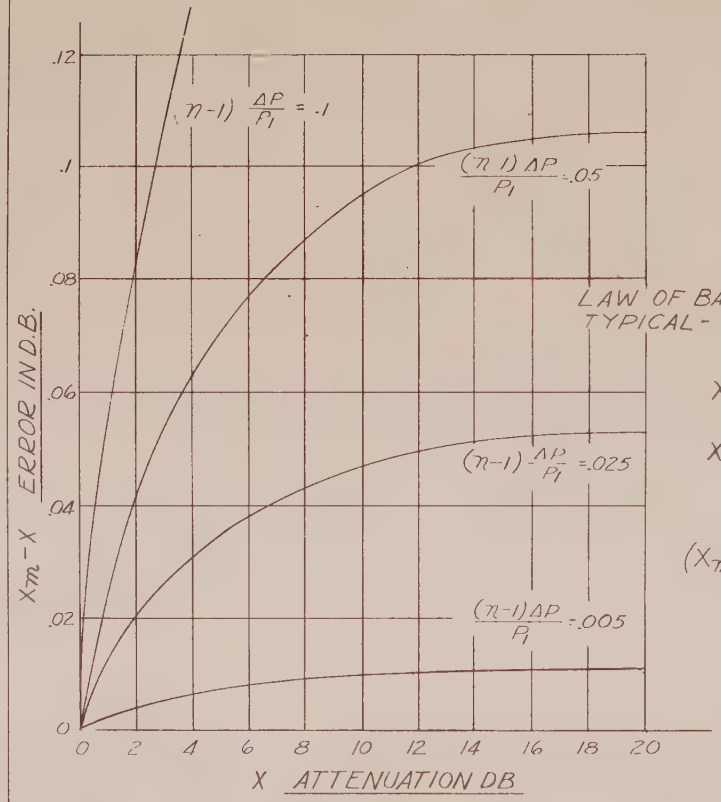
TYPICAL INSERTION LOSS TEST SET
RANGE 0 – 30 db



VIEW OF INSERTION LOSS TEST SET
SHOWN IN BLOCK DIAGRAM B-114-30

TOLERANCES

ALL 3 PLACE DECIMAL DIMS. ± .003
ALL 2 PLACE DECIMAL DIMS. ± .01
ALL FRACTIONAL DIMS. ± 1/64
ALL ANGLES ± ½°
UNLESS OTHERWISE SPECIFIED



X = ATTENUATION IN DB
ΔP = MAX. R.F. POWER (PEAK) AT 0 DB
P_1 = D.C. BIAS POWER
$\Delta P'$ = R.F. POWER (PEAK) WITH ATTENUATOR INSERTED
X_m = MEASURED ATTENUATION IN DB BY ASSUMING PERFECT SQUARE LAW ($n = 1.0$)

LAW OF BARRETER - $R \cdot R_0 + J D^n$
TYPICAL - $n = .9$ FOR SPERRY #821

$$X = 10 \log_{10} \frac{\Delta P}{\Delta P'}$$

$$X_m = 10 \log_{10} \left[\frac{\Delta P}{\Delta P'} + \frac{(n-1)\Delta P(\Delta P - \Delta P')}{2 P_1 \Delta P'} \right]$$

$$(X_m - X) = 10 \log_{10} \left[1 + \frac{(n-1)\Delta P}{2 P_1} (1 - 10^{-X/10}) \right]$$

ERROR IN ATTENUATION MEASUREMENT DUE TO DEPARTURE OF BARRETTER FROM SQUARE LAW

SLIDE NO. 6

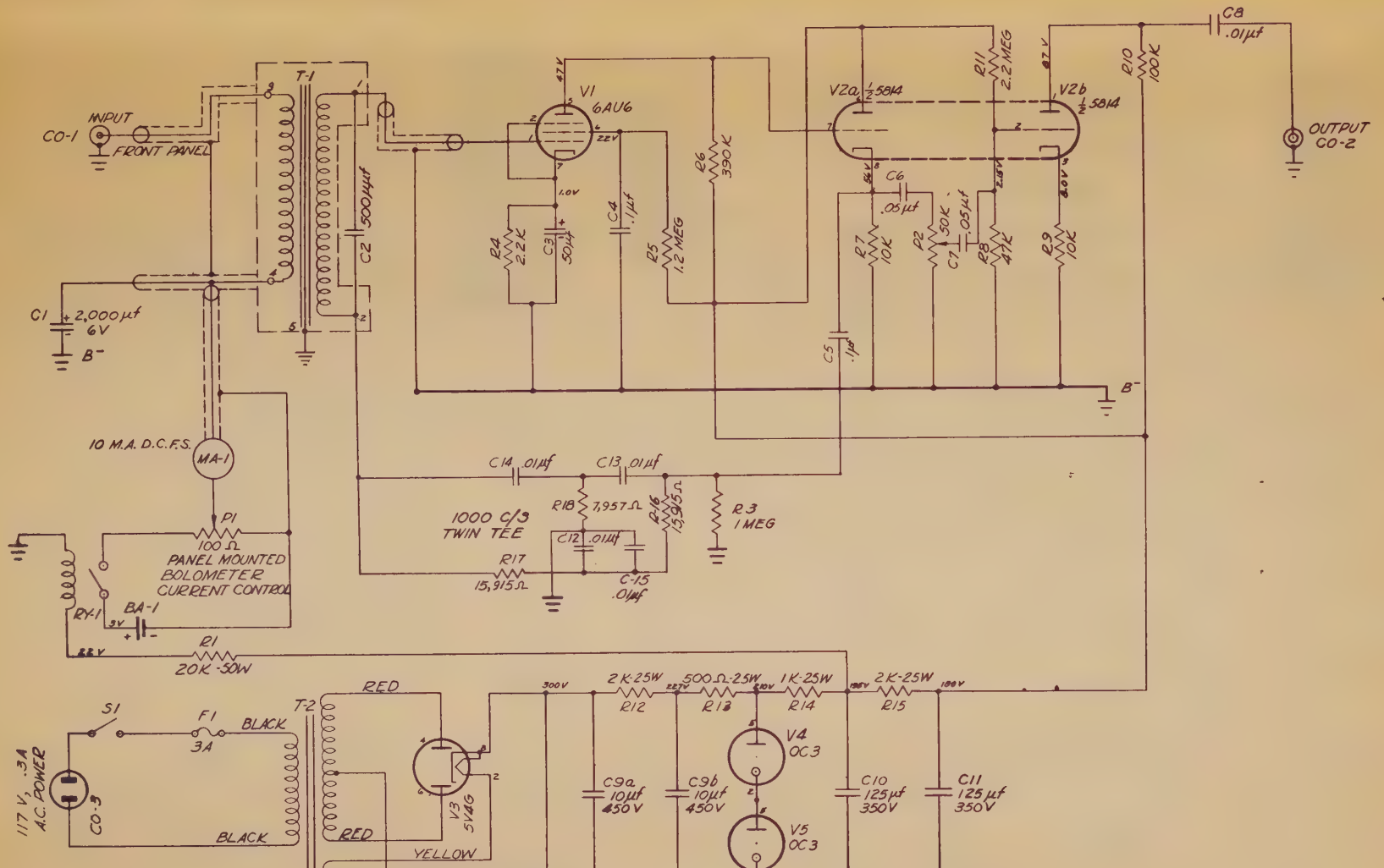
REVISIONS		
A	REVISED - 1-13-55	

USED ON	ASSY. DRWG.

Weinschel Engineering Co.
SILVER SPRING, MD.

ERROR IN ATTENUATION MEASUREMENT DUE TO DEPARTURE OF BARRETTER FROM SQUARE LAW

MATERIAL
FINISH
D 6-15-54 C
T
SCALE
B 114-33 A



REVISIONS			
REVISED	P-23-54	D.A.C.	
REDRAWN	3-27-54		
REVISED	5/21/55	D.A.C.	
REVISED	5/24/56	JDC	
REVISED	12-8-57		
REVISED	1-10		
REVISED	4/19/57	D.A.C.	

USED ON	ASSY. DRWG.
BA-1A	

Weinschel Engineering Co.
SILVER SPRING, MD.

SCHEMATIC
BOLOMETER PRE-AMPLIFIER

MATERIAL

FINISH

D3-27-54 C

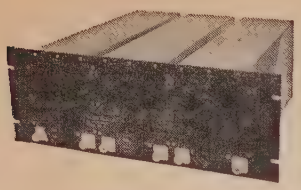
SCALE

C 112-7

F

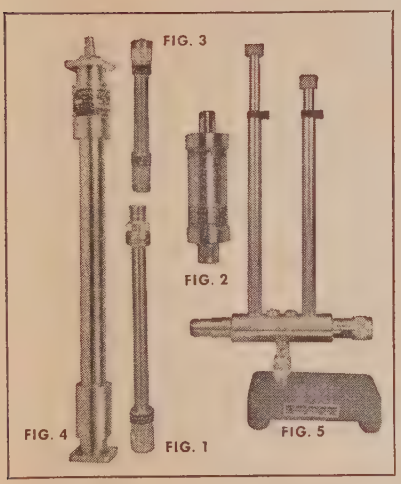
For Standards of Attenuation Use Weinschel Engineering Co.'s Coaxial Pads

STEP ATTENUATORS



PRECISION STEP ATTENUATOR MODEL #64. The only step attenuator containing low V.S.W.R., 0.1 db steps. Three drums cover the range of 0-64 db in steps of 0.1 db from DC to 1,000 MC. Long life switches and exceptional stability are among the reasons this instrument is used by standard laboratories who cannot afford to make mistakes. Impedance is 50 ohms, connectors type "N"; power capacity 100 mw. CW Calibration chart showing insertion loss, and V.S.W.R. at DC and 1,000 MC supplied. Change of insertion loss of all pads between 0 and 10 db does not exceed .1 db between DC and 1,000 MC, and 0.1 db per 10 db at 1,000 MC for pads between 20 and 50 db. Accuracy of pads at DC is better than .05 db to 10 db, and 0.1 db to 50 db. Ask for Bulletin #37.

COAXIAL ATTENUATOR PADS



Design and Manufacture of Coaxial Pads to Specific Requirements Is Our Specialty.

Not shown is our Model 50 attenuator pad. It has small attenuation errors from DC to 1,000 MC, and is available in steps of 1 db in range 1-10 db and 10 db steps in the 10-40 db range. Accuracy at DC is .05 db from 1 to 10 db, and .1 db between 20 and 40 db. Frequency sensitivity not greater than .2 db from DC to 1 KMC, except for the 30 and 40 db pads which have .3 and .4 db. Will handle average powers of 1 watt with proper termination, and 1 KW peak. Ask for Bulletin #44.

Fig. 1: Type 210 Pad, "lossy line" construction, 50 ohm impedance, with type "N" connectors. Frequency range 1 KMC to 10 KMC; loss range 3, 6, 10, 12, 20 db. Average power varies from 5 to 1 watt, peak power from 10 to 2 KW. Also available with type "C" connectors. Ask for Bulletin #17.

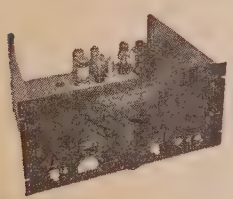
Fig. 2: Precision Power Pads, 50 ohms impedance, type "N" connectors, ±.1 db accuracy from DC to 1,000 KMC. Model 10, 10 watt power pad, "T" type, range 1-3 db, bilateral with male and female connectors. Model 11, range 4-10 db, is unilateral with female input and male ouptut.Model 12, same range as model 11, is also unilateral with male input, and female output. Maximum input V.S.W.R. 1.10. Ask for Bulletin #27.

Fig. 3: "S" Band attenuators, 50 ohms impedance, type "N" connectors, CN 42, CN 43, CN 29, provide insertion losses of 10, 16, and 20 db. Our commercial versions cover the range 1-20 db in models, 301, 303, 306, etc. (1 db, 3 db, 6 db, etc.). Also similar are types 410, and 416 having an OD less than ¾" for use with TS-125 power meter, Ask for Bulletin #43.

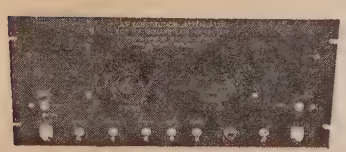
Fig. 4: ⅞" Rigid Line Pad, types CN 168, CN 169, CN 110, provides losses of 3, 6, and 10 db. Frequency range is 1 KMC to 4 KMC. Max. average power input is between 10 and 5 watts, peak power input is between 20 and 10 KW. Also available for ⅞" rigid line are type 46 pads with frequency range from DC to 1 KMC and insertion losses of 3, 6, 10, and 20 db. Ask for Bulletin #42.

Fig. 5: Double Stub Tuner; Model DS 109 covers 750 MC to 10 KMC, and model DS 109L covers 400 MC to 4 KMC. Stub tap positions are adjustable facilitating ease of adjustment for impedance matching. The specially designed shorts carry low current through the sliding contacts giving exceptionally smooth adjustment. Ask for Bulletin #19.—

INSERTION LOSS TEST SETS, PARTS FOR:



BOLOMETER PREAMPLIFIER MODEL BA-1: Measures insertion loss between 0 and 30 db at low R. F. power levels in conjunction with recommended bolometer and VTVM. Bolometer burnout from other than R-F overload is practically impossible. Bolometer can be inserted and removed without disconnecting DC. Combined with low noise level are freedom from hum pickup, and wide dynamic linear range of 60 db with linearity better than 0.1 db. Frequency is 1 KC with band-width of 35 cps. Adjustable gain, 10,000 maximum. Equivalent input noise from 200 ohm source less than 30×10^{-9} volts RMS. Input impedance above 2,000 ohms for operation from 200 ohm Bolometer. 30 volts max. linear output into 1 megohm. Ask for Bulletin #23.



CATHODE FOLLOWER MODEL CF-1: Input impedance matches output of BA-1 Bolometer Preamplifier. Utilizes a 2,000 ohm precision attenuator with an accuracy of .01 db at 1 KC; eliminates errors in insertion loss measurements caused by accuracy limitations of VTVM. For further details ask for Bulletin #38.

MODULATED OSCILLATOR MODELS MS-1, MS-2, MS-3, R. F. sources for insertion loss measurement, cover the frequency ranges 50-250 MC, 250-920 MC, and 900-2,000 MC with 1 KC ± 5cps. square wave modulation (100%). Minimum peak output is 100 MW into 50 ohms with excellent long-time amplitude stability. Ask for Bulletin #40.

OTHER PRODUCTS

KEYBOARD OSCILLATOR MODEL 150: Used extensively for checking filters where it is necessary to explore small portions of the curve in detail. Covers range from 1 to 100,000 cycles with rapid, accurately repeated, frequency selection. Drift less than 0.02% per hour. Steps of .1 cps. to 1 KC, 1 cps. to 10 KC, continuous tuning to 10-100 KC. Full details in Bulletin #41.

POWER PULSE GENERATOR MODEL PG-1, for the generation of high power pulses for testing of components by video pulses. Output: maximum of 1,500 volts into 50 ohms, with pulse lengths of 1 to 5 microseconds, variable in 1 microsecond steps, and PRF of 20 to 2,000 cps limited by the capacity of the power supply. Ask for Bulletin #39.

MODIFICATION OF STD. PRODUCTS. There is now available in the microwave field a wide range of Weinschel engineered coaxial attenuators. In most cases this selection is large enough to cover the needs of the average laboratory. However, if special requirements call for *modification* of standard equipment, our design department will gladly answer your inquiries.

CALIBRATION SERVICE: Our insertion loss calibration service for coaxial equipment, is available to certify up to 50 db from 50 MC through 10,000 MC. Two accuracies of measurement are available: A): .01 db per 5 db. B). .05 db per 5 db.

NOTE: Class "A" calibrations are usually not justified for coaxial equipment above 1,000 MC, due to inaccuracy of impedance measurements in coaxial devices.

We are also able to offer DESIGN and QUANTITY PRODUCTION of:

Bolometer Mounts, Thermistor Mounts, Insertion Loss Test Sets, Coaxial Terminations, Power Measuring Bridges, Micro Potentiometers

Weinschel Engr. & Mfg. Corp.

10505 Metropolitan Avenue, Kensington, Md. Lockwood 4-0123

WEINSCHEL ENGINEERING
KENSINGTON, MARYLAND
Test Record

BOLOMETER PREAMPLIFIER

Model No. BA-1B
Serial No. 78
Job No.
CUSTOMER
Date 6/9/58

1. Gain:

Input = 1 MV Output 11 VRMS

2. Linearity:

Input	Deviation From Linear
3 MV	0 db
-2 db	less than .05 db
-4 db	" " " db
-6 db	" " " db
-8 db	" " " db
-10 db	" " " db
-12 db	" " " db
-14 db	" " " db
-16 db	" " " db
-18 db	" " " db
-20 db	" " " db
-22 db	" " " db
-24 db	" " " db
-26 db	" " " db
-28 db	" " " db
-30 db	" " " db

3. Gain Stability:

E_{line} = 105 V AC
Input 3 mVrms Deviation 0 db

E_{line} 125 V AC
Input 3 mVrms Deviation <.2 db

Serial No. 78
Model No. BA-1B
Job No. _____

4. Selectivity and Band Width

Resonant Frequency: 999.9 CPS
High Frequency 3 db Point: 1015.3 CPS
Low Frequency 3 db Point: 983.8 CPS

5. Noise:

With 200 ohm in Input and Maximum Gain:
Output Noise Voltage .29 mVrms

Tested by J. Geniak

Engineer _____

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